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FUSAIN

BY

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FUSAIN [1]

By Joseph D. Davis[2]

The term "fusain" was first adopted from the French by the American geologist J. J. Stevenson in 1911, according to Wheeler, (1),[3] who applies it to that portion of coal resembling charcoal, which he treats as one of the four ingredients of banded bituminous coal. The term has since been adopted by American writers. The Germans use it with slightly different spelling - namely, fusit. It is the equivalent of "mother-of-coal" and "mineral charcoal" of the earlier British writers. The English word fusain is also applied to "a crayon of fine charcoal" and is derived from the Latin root fusus.

OCCURRENCE OF FUSAIN IN COAL AND ITS RECOGNITION

Fusain is fairly widely distributed in coals of all ranks in varying amounts. It is almost always present in very thin sheets between the bedding planes of the banded coal constituents and presents a jet-black silky appearance when the coal is split away. As fusain has little cohesive power the coal splits readily along the planes where it occurs. Such fusain bands often attain appreciable thickness -- frequently 1/4 to 3/4 inch. Beet (2) has reported a maximum thickness of 2 inches for fusain partings, and Sinnatt (3) has found it in the form of plates and lumps; one lump taken by him from the Peacock mine weighed 3-3/4 pounds. Bode (4) has found it in coal balls. Sinnatt (3) states that fusain occurs in two forms, "the first a hard compact variety occurring rather rarely, which can not be pulverized by pressure of the fingers; the second type is the common substance" -- that is, a very friable, easily pulverized material. The writer has also found the two types of fusain in the same coal bed and has observed that the hard variety contained considerable calcium carbonate, which probably entered the material in situ by infiltration. Sinnatt further remarks that the layers of fusain (soft type) usually contain less moisture than the coal (or lose it more readily on exposure), and when exposed they quickly change to flocculent powder so that the fines of the coal as mined are likely to contain a major proportion of this substance.

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[2] Chemist, U. S. Bureau of Mines.

[3] Figures in parentheses refer to the bibliography at the end of this circular.

Recognition

Fusain is a steely black substance and when reasonably pure may be readily distinguished from bituminous coal, in which it occurs. The "streak" of the coal is brown, whereas that of fusain is black. The difference in color is easily apparent in fine powders of the substances. The microscope, however, offers a more certain means of identification in the hands of an experienced observer. The requisite experience is not extensive; a few hours study of known samples of fusain and of known mixtures of coal and fusain is sufficient. The writer prefers to use a binocular microscope of about 70 diameters magnification with the sample in powdered form, lighted directly. The fusain particles under these conditions will present a fibrous appearance, or in the case of the larger particles that of bundles of fibers. Plainly this structure is that of the plant matter from which the fusain was derived. It shows little distortion. In the case of the coal substance, although this is of plant origin, the material has been so macerated in the normal coalification process that its structure is hardly evident at magnifications as low as 70 diameters. If the sample is chiefly coal detection of the fusain by this method becomes difficult. With coal of 60-mesh size it is perhaps possible to detect fusain when as much as 6 per cent of it is present. When it is desired to detect small inclusions of fusain in the coal mass the method involving the making of thin sections of the coal and examination under higher magnification by transmitted light is available. This method, however, requires special training in the making of sections and more experience in the use of the microscope than is usually possessed by a research chemist. Reinhardt Thiessen, microscopist and research chemist of the U. S. Bureau of Mines, is especially skilled in the use of this method and has developed it to a high degree.

Cooper (5) determined the amount of fusain in samples of coal from 15 mines three producing anthracite, three slightly anthracitic coals, and nine bituminous coals. The fusain varied from 1.5 to 4.0 per cent in the first case, 1.0 to 4.5 per cent in the second, and 0.0 to 2.5 per cent in the third. Sinnatt (6,7) states that the fusain content of coal may make up 5 per cent of the coal bed; this agrees with the above figures.

Separation and Determination

Apparently no very precise methods for separation and determination of fusain are available. Beet (2), in presenting analyses of various fusains, remarks that the results

> "alone suffice to show that they [the fusains] contained in many instances considerable proportions of material which, though not recognizable as coal, was not true fusain. It seems probable that the conflicting results that have been elsewhere reported for the analysis of fusains (as compared with the coals with which they were associated) and for its properties, such as rate of oxidation, may be due in part to the samples examined being mixtures of fusain with more or less coaly matter."

The writer of this present paper, knowing the difficulty of obtaining samples of fusain which will not show small quantities of foreign matter under the microscope, believes that this is an important consideration which should be borne in mind where published properties and analyses of fusain are concerned. Brief mention of methods used for determination of fusain will suffice here; those interested in going deeper into the subject are referred to the original papers. Sinnatt (3) calculates the fusain content of a mixed sample from its volatile-matter content; the volatile matter of fusain and that of coal are known from analyses of pure samples of these constituents of the mixture. Stern (8) uses a similar method. Beet (2) separates by screening. Lessing (9, 10) uses the principle of elutriation, "float-and-sink" methods, and disintegration by acids -- for example, by sulphur dioxide.

ORIGIN OF FUSAIN

Authorities on the origin of coal do not agree as to the manner of formation of fusain. Obviously it was woody matter originally (this is apparent from its structure), but the nature of the carbonizing process it went through before arriving at its present state is not clear. Because of its presence in all ranks of coal in the same form it seems that the carbonizing process must have been complete in the early stages of coalification -- that is, in the peat bogs (11). The oldest and simplest theory to account for its presence in coal is that of Daubree (12), who believes that it originated in forest or bog fires. Jeffrey (13) in America and Bode (4) in Germany are authorities who prefer the forest-fire theory, whereas Thiessen and White (14) are inclined to think that fusain was formed by special conditions of decay in the peat bog. Similar ideas are held by Stach (15) in Germany. The following quotation from Thiessen (16) will illustrate the reasoning of those opposed to the forest fire theory:

> "Plant Matter Buried Alive
>
> It has been mentioned that a considerable number of trees (in peat bogs) recline more and more until they lie flat and eventually are buried alive. Secondly, the root complex of the flora of the swamp, while they never penetrate far into the peat stratum below, living roots remaining relatively near the surface by the time they die are covered by a considerable amount of debris. Such plant matter evidently does not go through the same phases of decay as those that decay on the surface with complete access of air****Decay under such conditions in probably extremely slow. Fungi are excluded at all times and reasoning from the chemistry of wood decay, cellulose-fermenting bacteria only can be active, living under strong reducing conditions, fresh peat being a strong reducing agent. We may have here a solution of the origin of mineral charcoal."

McKenzie Taylor (17) accounts for the formation of fusainlike material by anaerobic decay in peat under clay overburden impervious to air.

One objection to the forest-fire theory may be mentioned: If this were the manner in which fusain was formed one would expect to find it more localized and not so widely distributed in the bedding planes of the coal. Furthermore, one would expect to find occasional large logs in charred condition -- crushed perhaps, but remaining largely in situ. The forest-fire school believes that charcoal formed in the bog may well have been disintegrated and widely distributed by wind and water currents. The present writer does not venture judgment as to the comparative merits of these theories; they are presented merely to indicate the trend of thought of best known investigators in the field.

PROPERTIES OF FUSAIN

Physical

As previously indicated, fusain has fibrous or needlelike structure, and for this reason when mixtures of coal and fusain are passed through a sieve of given mesh the fusain particles will be the larger because of their great length compared to their thickness. Fine sizes of fusain (150-mesh and finer) do not have as strong a tendency to agglomerate as do fine coal particles. The mutual attraction of coal particles (surface forces) in air is greater than that of fusain particles. Very fine coal particles tend to stick to fusain, thus obscuring its structure in a mixture under microscopic examination. The writer has been unable to find specific gravity figures for fusain except on one sample, for which the true specific gravity found was 1.53. Greenwood (18) gives the following comparative figures (Table 1) for cokes from fusain, durain, clarain, and vitrain.

Table 1.- True and apparent specific gravities and porosity of cokes from banded constituents of coal, according to Greenwood

	Fusain	Durain	Clarain	Vitrain
True specific gravity	1.980	1.877	1.880	1.878
Apparent specific gravity	1.980	.980	.600	.553
Per cent porosity	.0	48.9	68.0	70.7

Sinnatt (3) observes that

> "fusain ignites with considerable ease at a low temperature and continues to smoulder at a dull red heat****The fact that little odor is produced adds to the dangers associated with the combustion of fusain, as practically no indication is afforded of the substance being on fire."

Chemical

As fusain is very similar to charcoal it will be expected to have very similar chemical properties; this is true except as it may have become mixed with or absorbed both organic and inorganic materials of the coal bed. On destructive distallation it always yields considerable gas and a very little tar, but it is entirely devoid of coking power. The following results (Table 2) reported by

Greenwood (18) will illustrate its behavior on distillation as compared with that of other coal constituents:

Table 2.- Comparative yields of products from banded constituents of coal on destructive distillation, according to Greenwood

Sample	Coke, per cent	Tar, per cent	Liquor per cent	Gas, c.c. per 10 grams
Vitrain	65.7	7.7	8.0	3465
Clarain	65.4	8.9	7.5	3390
Durain	62.3	12.1	5.9	3280
Fusain	80.3	3.6	4.8	2400 (very lean)
Coal, true sample	66.8	8.9	7.5	3100

Sinnatt and Slater (19) have brought out the interesting fact that low-temperature propagation of combustion will not take place in 60 to 90 mesh coal alone; but if some fusain is added, combustion propagates. One supposes that the rapid low-temperature absorption of oxygen by fusain is the controlling factor; the fusain is an accelerator, so to speak, which causes combustion to propagate in coal normally too coarse to exhibit this phenomenon.

Fusain is practically insoluble in organic solvents ordinarily used in the extraction of coal and is not hydrogenated to an appreciable extent under pressure. Shatwell and Graham (20) give the following comparative figures for hydrogenation of the banded constituents of a bituminous coal: Clarain gave 56.2 per cent of oil soluble in ether in three hours treatment and durain gave 37.5 per cent soluble after four days treatment, whereas 95 per cent of the fusain remained insoluble after four days.

Fusain is not considered promising as a decolorizing agent, doubtless because of the mineral matter and coal substance it has already absorbed.

Composition

The composition and properties of charcoal depend upon the kind of wood from which it is made (21), the degree of carbonization (22), and the conditions of exposure (23) after being carbonized. As fusain is a very similar material (whether we accept the forest-fire theory or not) one would expect its composition to be subject to similar variations. The influence of conditions to which it has been subjected after formation probably has greater importance than with charcoal because of the long periods involved in coalification of the material in which the fusain is distributed. One would expect, for example, that its volatile-matter content would vary diredtly with that of the coal substance; this is the basis of Sinnatt's method for estimation of fusain previously referred to. The relation is not necessarily precise, however, because the volatile matter of the fusain itself may vary as noted above, and it may not have attained equilibrium as regards absorption of volatile matter from the coal. Furthermore, and this seems most important, as Beet (2) has remarked, it is extremely difficult to obtain coal-free fusain for analysis. From analyses examined by the writer it appears that, in general, the higher the volatile matter of the coal the higher will be that of the fusain. A number of analyses of fusains together with analyses of coals in which they are associated are given in Table 3 to show the general relation, but it is not considered that the data available are sufficient to prove the case.

It is worth noting here that the few mine samples of fusain analyzed by the Bureau of Mines show an abnormally high moisture content as compared with the rest of the coal. The moisture content will run from 18 to 40 per cent, whereas that of the coal is not over 3 per cent. All but a fraction of 1 per cent of the moisture in the fusain, however, is removed by "air-drying." This agrees with the observation of Sinnatt, referred to earlier in this paper, that fusain contains large amounts of loosely held moisture.

It will be noted from Table 3 that the moisture, oxygen, hydrogen, and nitrogen content (except in one case) of the coal is higher than that of the fusain, as would be expected from what has been said in the foregoing. The sulphur is sometimes higher in the fusain than in the coal and sometimes lower. As pyrite is often found associated with fusain one would expect to find high pyritic sulphur in coals where the sulphur content of the fusain is high. The total carbon of the fusain is higher than that of the coals but sometimes lower than that of the vitrains. The volatile-matter content is always higher for the coal than for the fusain, but it can be seen that coals highest in volatile matter are not always associated with fusains of highest volatile matter. This in itself should not be taken, however, as argument against the use of the volatile-matter ratio for determination of fusain, provided that the volatile matter of pure coal and that of pure fusain for the coal in question are known.

Table 3.- Analyses of fusains and coals associated with them

Coal	Sample	Moisture	Ash	Volatile matter	Organic volatile	Carbon	Hydrogen	Oxygen	Nitrogen	Sulphur	B.t.u.
		(a) Analyses reported by Beet (2) (as received), per cent									
Barnsley Yorkshire Main	Coal	3.2	2.3	35.3	-	81.7	5.16	10.73	1.24	1.17	-
	Fusain	2.4	8.4	13.4	-	93.7	2.71	2.61	.44	.54	-
Ellcoal, Shields Colliery	Coal	10.8	1.3	35.9	-	81.0	4.91	11.73	1.37	.99	-
	Fusain	2.5	5.5	20.2	-	85.75	3.34	9.34	.46	1.11	-
Barnsley Top Softs	Coal	6.5	2.7	36.6	-	80.0	4.8	12.68	1.46	1.06	-
	Fusain	2.1	15.2	20.6	-	93.43	2.23	2.49	.40	1.45	-
Top Slipper Hamstead	Coal	8.0	4.4	37.7	-	79.6	4.77	12.58	1.18	1.87	-
	Fusain	2.9	18.0	17.7	-	89.43	3.26	6.11	.51	.69	-
Dysart Main Balgonic	Coal	10.5	4.5	39.6	-	78.80	5.09	14.68	1.08	.35	-
	Fusain	4.3	7.0	20.5	-	86.05	3.39	9.08	.61	.37	-
Deep Seam Aldridge	Coal	6.0	4.6	39.6	-	80.9	5.41	11.72	1.08	.89	-
	Fusain	1.9	5.1	13.7	-	90.48	2.83	5.74	.44	.51	-
Ell Seam Bog Colliery	Coal	7.4	3.1	39.7	-	80.20	5.14	12.31	1.47	.88	-
	Fusain	1.6	2.0	14.0	-	92.43	2.86	4.04	.41	.26	-
Robins Seam Cannock	Coal	8.9	8.3	39.8	-	73.50	4.82	15.34	1.48	4.86	-
	Fusain	2.2	15.2	17.0	-	85.97	2.93	4.91	.39	5.80	-
Deep Softs Mapperly	Coal	9.8	7.7	40.4	-	75.60	4.71	16.50	1.88	1.31	-
	Fusain	2.3	9.7	16.4	-	90.25	2.98	4.64	.48	1.65	-
Deep Softs Derby	Coal	7.6	13.2	40.9	-	74.0	4.80	14.51	1.51	5.19	-
	Fusain	2.6	6.4	17.9	-	89.53	3.0	5.79	.67	1.01	-

Table 3 (cont'd)

Coal	Sample	Moisture	Ash	Volatile matter	Organic volatile	Carbon	Hydrogen	Oxygen	Nitrogen	Sulphur	B.t.u.
		(b) Analyses reported by Sinnatt (3) (as received)									
Bacon Mine	Coal	2.16	3.72	40.19	38.03	76.96	5.01	10.63	1.62	1.98	14,050
Upper King	Fusain	1.23	10.86	19.9	18.67	77.30	3.82	5.47	.79	1.62	13,423
Mountain	Coal	2.73	3.52	26.46	23.73	-	-	-	-	-	-
Mine	Fusain	.45	7.14	9.52	8.87	-	-	-	-	-	-
Hell Hole	Coal	1.94	2.67	35.0	33.06	82.25	5.34	7.05	1.62	1.02	14,589
Mine	Fusain	.70	6.71	15.97	15.27	83.26	3.27	2.51	.84	3.36	14,015
Arley	Coal	1.92	3.23	35.34	33.42	82.32	5.51	5.89	1.54	1.45	14,740
Mine	Fusain	1.40	4.72	13.21	11.81	84.63	3.24	4.47	.76	2.11	14,700
Ravine	Coal	2.42	4.05	36.56	34.14	78.42	5.24	8.41	1.50	2.28	14,360
Mine	Fusain	1.50	11.52	15.80	14.30	76.85?	3.47	4.69	.73	2.85	12,880
			(c) Miscellaneous Analyses								
					Fixed Carbon						
Top Hard (27)	Vitrain	9.90	0.90	29.43	59.77	71.77	4.75	10.26	1.15	1.27	--
	Fusain	3.10	13.80	16.87	66.23	72.47	3.19	5.97	.79	.68	--
Winterslag (27)	Vitrain	.7	3.1	20.49	75.71	84.37	4.43	4.71	1.80	.85	--
	Fusain	.6	11.4	14.08	73.92	79.02	3.61	3.70	1.00	.69	--
Andre (27)	Vitrain	.6	2.1	28.90	68.40	84.85	4.48	4.86	2.06	1.10	--
Dumont	Fusain	.4	7.4	12.91	79.29	83.62	3.14	3.78	.96	.76	--
Limbourg (27)	Vitrain	.6	3.9	26.45	69.05	82,03	4.20	6.40	1.95	.99	--
Meuse	Fusain	.4	10.8	13.76	75.04	77.61	3.28	4.08	2.74	1.03	--
Bruckenberg	Bright Coal	8.40	2.27	29.30	60.03	75.02	4.72	7.68	1.46	.45	--
Coal (27)	Fusain	1.38	30.58	27.02	48.42	56.03	2.36	8.93	.39	.33	--
English	Vitrain	12.6	1.2	38.6		78.5	5.15	13.9	1.33	1.12	--
Coal(3)	Fusain	3.9	10.9	22.6		84.7	3.9	9.7	1.05	.65	--

PRACTICAL SIGNIFICANCE OF FUSAIN IN COAL

As fusain has no coking power itself it undoubtedly detracts from the coking power of the coal in which it occurs. However, as it is usually present in small quantities it is difficult to see how this could become an important factor practically, unless the coal is deficient in coking power or unless, due to methods of mining and preparation for coking, there is concentration of fusain in the coal as charged. It is known, for example, that fusain tends to concentrate in the fine sizes. In this connection a point recently brought out by Rose (25) seems very important and deserving of thorough investigation. He has shown that segregation of patches of fusain in coke greatly weakens its structure, and it is readily recognizable as such with practically unchanged structure in the coke. It seems, therefore, that the distribution of fusain in coal may have a much more important bearing on the quality of coke produced than its amount. Thus, relatively thin sheets of fusain in the coal may effect the strength of a relatively large proportion of the sized lumps of coke as marketed.

Tideswell and Wheeler (26) believe that the presence of fusain may increase the tendency of a coal to heat spontaneously because of its rapid absorption of oxygen at low temperature. This, however, has not been substantiated by other investigators.

There is no doubt that fusain increases the dustiness of coal because of its great friability. It is the smudgy black material found on lumps of coal along their bedding planes and easily rubs off, soiling the hands on handling. It dries quickly and falls from the coal in the form of dust.

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